# STUDY AND REALIZATION OF DEFECTED GROUND STRUCTURES IN THE PERSPECTIVE OF MICROSTRIP FILTERS AND OPTIMIZATION THROUGH ANN

Bhabani Sankar Nayak[1], Subhendu Sekhar Behera[2], Atul Shah[1]
[1] BTech, Department of ECE, National Institute of Science & Technology, Berhampur
[2] BTech, Department of CSE, National Institute of Science & Technology, Berhampur

***ABSTRACT***

*Defected ground structures (DGS) have been developed to enhance different characteristics of many microwave devices. In this paper a Micro-strip low pass filter with Dumbbell Shaped Slot Defected Ground Structure (DGS) is designed. The response of the filter is analyzed with respect to variation in dimension of the DGS unit .The variation of dimensions of defects studied with their corresponding change in capacitance, inductance as well as frequency response. The defects dimensions are modeled with respect to frequency using the artificial neural network. Optimizing the convergence of Artificial Neural Network (ANN) classifiers is an important task to increase the speed and accuracy in the decision-making. The frequency response of the micro strip filter is modeled with respect to the variation in dimension of DGS using CST microwave studio. The dimensions are further optimized in order to achieve minimum error in frequency response. Incremental and online back propagation learning approach is followed in the training of neural network because of its learning mechanism based upon the calculated error and its ability to keep track of previous learning iteratively. The simulation results are compared with the results obtained through ANN and the designs are further optimized.*

***KEYWORDS:*** *Filters, defected ground structures, ANN, CST microwave studio.*

## I. INTRODUCTION

Defected Ground Structures (DGS) have been developed in order to improve characteristics of many microwave devices [1]. Most of its advantages lies in the area of the microwave filter deign, microwave oscillators, microwave couplers as well as microwave amplifiers. DGS is motivated by the by the study of Electromagnetic band gap structures [2]. It is more easily an LC equivalent circuit. Presently there are vast applications of microwave components such as filters, amplifiers, couplers, antennas in various fields like mobile radio, wireless communication, and microwave millimeter wave communication [4]. Basically micro strip technology consists of transmission line made of conducting material on one side of dielectric substrate with the ground plane on other side. A microwave filter is a two- port network used to control the frequency response at a certain point in a microwave system by providing transmission at frequencies within the pass band of the filter and attenuation in the stop band of the filter. Defected ground structures (DGS) are recently one of the hottest topics which are researched in microwave domain, which developed from the photonics band gap (PBG) structures [1]. The high characteristic impedance of DGS is also used in digital systems [2]. DGS is an etched lattice which makes one or a few of PBG etched ground elements in the ground plane. DGS can achieve high-performance which can not be obtained by conventional technology. Because of the advantage of DGS, such as having small structure size, more transitional sharpness, achieving broader stop band responses, high characteristics impedance and simple model, it has been widely used in the design of microwave filter. The defects in the ground plane of the transmission lines [3] such as dumbbell , elliptical , square etc disturbs the shield current distribution and also changes the characteristics of

transmission lines e.g. capacitance and inductance. The series inductance due to the DGS section increases the reactance of a micro strip with the increase of the frequency. Thus, the rejection of the certain frequency range can be started. The parallel capacitance with the series inductance provides the attenuation pole location, which is the resonance frequency of the parallel LC resonator. However, as the operating frequency increases, the reactance of the capacitance decreases. Thus, the band gap between the propagating frequency bands can be occurred. By etching DGS on the ground plane it is possible for the designer to increase the equivalent inductance L highly and to decrease the equivalent capacitance C at the same time, and finally to raise the impedance of the micro strip line to a level more than 200Ω[3]. But the problem arises, as there is no fixed mathematical model in order to relate the frequency response with respect to the change in dimension of DGS Unit cell. Our main focus lies in optimizing the frequency response with the help of ANN being trained with Back Propagation Algorithm [14]. Back Propagation is the most popular neural network training algorithm for supervised learning with weight correction rule [11]. The weight correction methodology comprises of back-propagating the errors from output layer to hidden layer, thus finding the optimal set of weights. It is used in a greater extent in the field of Data Analysis, Weather Forecasting, and Trading Analysis etc. As the Learning Rate has a significant effect on the results, we choose the best through iteration. This allows the Back Propagation to be optimized. The design procedure is presented in the section.2 along with its response due to the variation of different dimensions of DGS. The designs are implemented using CST microwave studio and the results are analyzed. In the 3rd section we implemented the back propagation neural network to model the frequency response with respect to the dimension of DGS. The application of artificial neural network ensures an optimum design methodology for microstrip filter design which is revealed when comparing the results with analytical methods and the results of the simulation software's [14]. The designs are made using the CST microwave studio software [15] and also the simulations for analyzing the frequency response for every change in dimensions of DGS, calculation of inductance and capacitance etc. ANN algorithm is implemented using C programming in DEV C++ compiler and the results obtained for training and testing is plotted with the help of MATLAB [15].

## II. A Study on Related Work

There has been a lot of research on optimization of frequency response using different soft computing algorithms. A novel approach for calculating the resonating frequency of microstrip antenna is presented in [14] by R.K. Mishra and A. Pattnaik. In the reference [4] A part of optimization is made to model the frequency response of the planar microstrip antenna with respect to the change in dimension of DGS. There are several algorithms to optimize the training process. Back Propagation is one of the most popular neural network training algorithms for supervised learning. The weight corrections are updated with a generalized delta rule to minimize the prediction error through iterations. There have been similar attempts made to choose the dielectric constant for antenna design using Neural network model [11]. In reference [13] a new methodology for determining the input impedance for microstrip antenna is presented. In this paper we have implemented the Artificial neural network algorithm to model the frequency response of microstrip filter with respect to the dimensions of dumbbell shaped DGS. The weight correction methodology comprises of back-propagating the errors from output layer to hidden layer, thus finding the optimal set of weights [7-9]. In this paper a feed-forward network (FFN) has been considered. FFN allows the signal to flow from input to output layer in feed-forward direction [7, 9].

## III. Design of Filter and Response Due to Defected Ground

The low pass filter configuration having five sections of alternating high and low impedances is shown in the figure1. The lpf was designed using the formulations depicted in [3].The order of filter designed is of 5th order. The Dumbbell Shaped Slot DGS section is fully described by two parameters the etched lattice dimension and gap distance. The influences of these two parameters on frequency characteristics of a micro strip are shown by simulations. All simulations were carried out on CST Microwave studio. The dimension of DGS slot are given below in fig2 as l,w,g respectively.

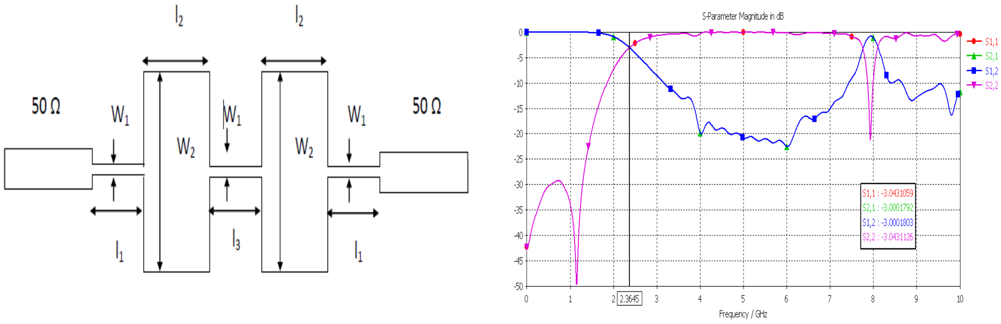



**Fig1**.design of low pass filter and its response

(Where the dimension are given by w1= 0.293 mm ,w2= 6.352 mm ,l1= 2.917 mm,l2= 7.1323 mm, l3=11.036mm,and the corresponding inductance and capacitance are given as L1 = 2.05 nH ,C2 =2.1472 pF, L3 = 6.634 nH, C4= 2.146 pF, L = 2.05 nH)
When the single dumbbell shaped slot is placed at the center, it provides inductance and hence by placing the DGS in the structure, effective inductance increases and the cut off frequency decreases.

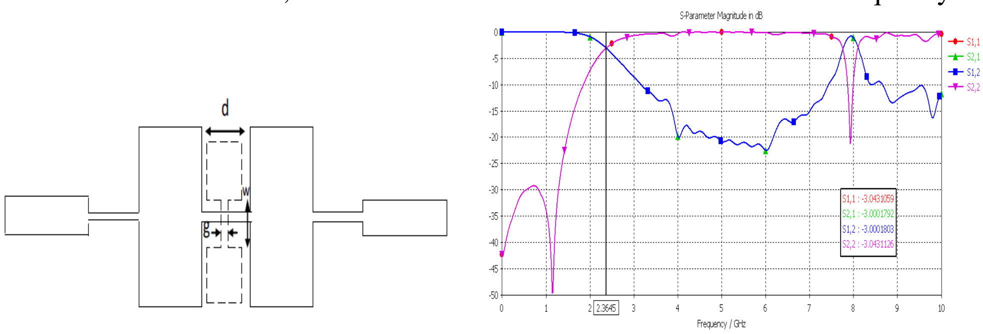



**Fig2.**design of low pass filter with defects and its response

The line width is chosen to be the characteristic impedance of 50Ω micro strip line for simulations. Three DGS unit circuits were simulated with the different dimensions. In order to investigate the influence of the square lattice dimension, the etched gap, which is related with the gap capacitance, was kept constant to 0.1 mm for all three cases and the etched square area was varied. The substrate with 0.762 mm thick and a dielectric constant of 3.2 is used for all simulations. We observe that employing the proposed etched lattice increases the series inductance to the micro strip line. This effective series inductance introduces the cutoff characteristic at certain frequency. As the etched area of the unit lattice is increased, the effective series inductance increases, and increasing the series inductance gives rise to a lower cutoff frequency, as seen in Table1. There are attenuation poles in simulation results on the etched unit lattices. These attenuation poles can be explained by parallel capacitance with the series inductance. This capacitance depends on the etched gap below the conductor line [4]. The capacitance values are identical for all cases due to the identical gap distance. However, the attenuation pole location, which corresponds to the resonance frequency of the parallel LC circuit, also becomes lower because as the series inductance increases, the resonance frequency of the equivalent parallel LC circuit decreases. The results are shown in table 1.

**Table1** variation of length and gap in DGS

| Variable(unit) | d =7 | d =8 | d =9 |
|---|---|---|---|
| Inductance(nH) | 5.24 | 6.39 | 7.56 |
| Capacitance(pF) | 0.70 | 0.69 | 0.67 |
| Cut off freq (GHz) | 1.70 | 1.48 | 1.34 |
| Center freq (GHz) | 2.59 | 2.36 | 2.21 |
| | G=0.1 | G=1 | G=2 |
| Inductance(nH) | 3.42 | 3.58 | 3.70 |

| | | | |
|---|---|---|---|
| Capacitance(pF) | 0.72 | 0.18 | 0.08 |
| Cut off freq (GHz) | 2.25 | 3.4 | 3.52 |
| Center freq (GHz) | 3.16 | 7.14 | 8.5 |

The lattice dimension is kept constant to 5 mm for all three cases and the etched gap distance is varied. Due to the constant lattice dimensions, we can expect that the effective series inductances are also constant for all cases. There is no change in cutoff frequency despite the variation of the gap distance. This means that the gap distance does not affect the effective series inductance of a micro strip. Variation of the effective capacitance only affects the attenuation pole location[1]. As the etched gap distance increases, the effective capacitance decreases so that the attenuation pole location moves up to higher frequency. When the single dumbbell shaped slot is placed at the center, it provides inductance and hence by placing the DGS in the structure, effective inductance increases and the cut off frequency decreases. When the single dumbbell shaped slot is placed at the center, it provide inductance and hence by placing the DGS in the structure, effective inductance increases and the cut off frequency decreases. Response is improved in terms of sharpness because of decrease in the capacitance. The Cut off frequency of the low pass filter is 1.66 GHz and the slope is 9.65 dB/GHz. When g is reduced to 0.1 mm the effective capacitance increases which results in lowering of attenuation pole location. The insertion loss reaches -50 dB down. As the area of the slot is kept constant, there is no change in effective inductance and hence the cut off frequency is constant. When the width of the etched slot is decreased effective inductance is decreased because of which cut off frequency is increased. Also the response is improved in terms of insertion loss and return loss.

**Table2 .** Variation with respect to the change in d

| S. No | D(mm) | Cutoff frequency(GHZ) | Slope (dB/GHz) |
|---|---|---|---|
| 1 | 6.3 | 2.4214 | 7.4808 |
| 2 | 6.1 | 2.4434 | 7.3361 |
| 3 | 5.9 | 2.4787 | 7.13 |

According to the Quasistatic Theory of DGS depicted in [4] the electric and magnetic fields are mostly confined under the microstrip line. The return current on the ground plane is the mirror image of the current distribution occurred at the strip line. The maximum surface current lies over the ground plane and the width of side filament arm which contribute to the inductance of DGS [4]. The gap is represented by the equivalent capacitances, the inductances and capacitances are derived from the physical dimensions using quasi-static expressions for microstrip crosses, lines and gaps given in [5]. The electrical equivalent model of DGS is given below [4,6] .it is been observed that for various change in dimension of DGS we are getting a different frequency for which any mathematical model is not established yet. So for the simplification we are implementing neural network in order to model the frequency change and optimize the design. In the next section we implemented the artificial neural network using Dev CPP compiler [15] for the training and testing of the network. This is validated with the simulations made at CST microwave studio on the desired set of testing data sets and also the frequency response is checked.

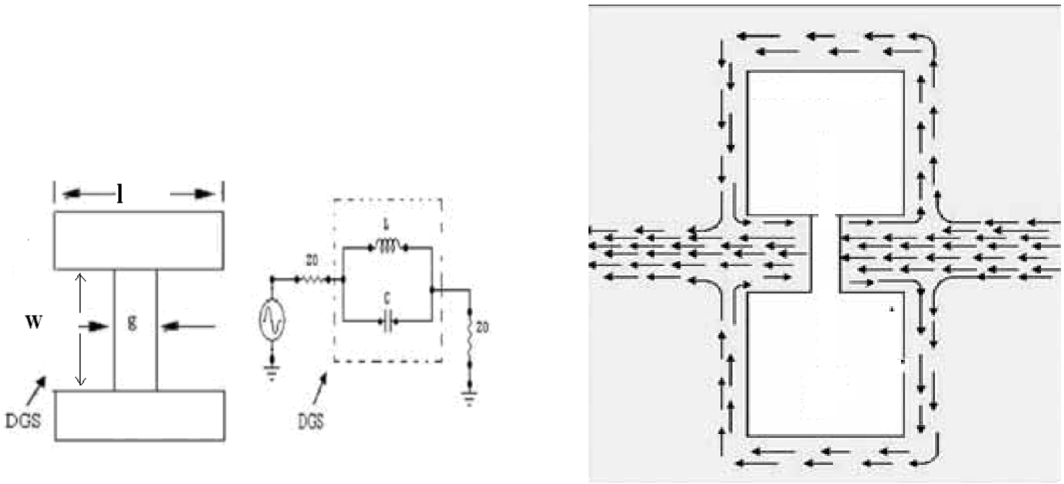



**Fig 3.** Equivalent circuit of DGS

## IV. OPTIMIZATION THROUGH ANN

Artificial neural network has been implemented to determine the problem of accurate determination of frequency of dumbbell shaped DGS for a desired dimension of DGS. The input to the ANN model are the dimension of defects l, w,g and the target data is frequency.

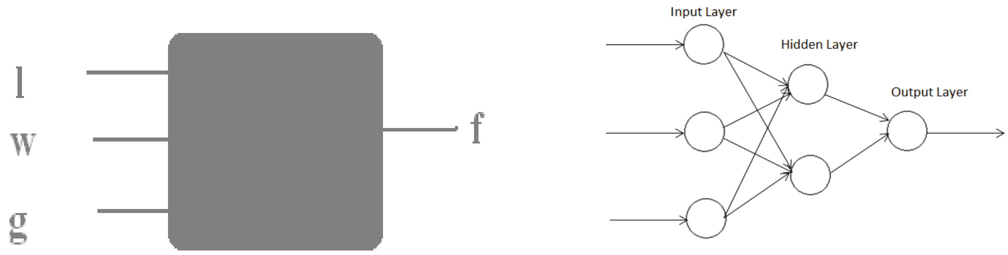



**Fig 4 .** ANN model of DGS

Back Propagation algorithm is implemented which comprises of two phases. First, a training input pattern is presented to the network input layer which is propagated forward to the output layer through hidden layers to generate the output. If this output differs from the target output presented then an error is calculated (Here Mean Square Error). This error is back-propagated through the network from the output layer to the input layer and weights are updated [7].

As we are not satisfied with a normal back propagation, we investigated the results with learning rate starting from 0.1 to *1.0* with momentum constant equal to *0.9* to speed up the learning process. The epoch size for each learning rate is *20 epochs* [7,8].The cost function used here is the Mean Square Error (MSE). The log sigmoid function in equation 1 is used as the transfer function associated with the neurons in hidden and output layer to obtain the normalized [0, 1] nodal outputs.

$$f(x) = (1+e^{-x})^{-1} \qquad (1)$$

As we use log sigmoid as the transfer function, we normalize the input values [0,1]. It will reduce calculation complexities. The class values for each dataset are also normalized in the range from 0 to 1.

## V. ALGORITHM

**Step1**: Set Learning Rate λ = 0.1, Momentum Constant α = 0.9. Initialize No. of Tuples according to dataset. Initialize set of weights randomly.

**Step2**: Set $MSE_{total} = 0$ and i=0.

**Step3**: Present $i^{th}$ input vector $X_{i0}$, $X_{i1}.....X_{iN-1}$ and specify the desired output $d_{i0}$. Calculate actual output $Y_{i0}$ and $MSE_i$.

**Step4**: Modify the weights starting from output layer to input layer using delta rule given below.

$$\mathbf{W_{jk}(t+1) = W_{jk}(t) + \lambda\delta_k x_j' + \alpha(W_{jk}(t) - W_{jk}(t-1))} \quad [2]$$

Where $W_{jk}$ (t) is the weight from node j to node k at time t; α is momentum constant; $x_j'$ is either the output of node j or is input j; λ is learning rate; and $\delta_k$, is an error term for node k. If node k is an output node, then

$$\boldsymbol{\delta_k = y_k (1- y_k) (d_k - y_k)} \quad [3]$$

Where $d_k$ is the desired output of node k and $y_k$ is the actual output.

If node k is an internal hidden node, then

$$\boldsymbol{\delta_k = x_j'(1 - x_j')\Sigma l\ \delta_l W_{kl}} \quad [4]$$

Where l is over all nodes in the layer above node k.

**Step5**: $MSE_{total} = MSE_{total} + MSE_i$.

**Step6**: Repeat by going to step3 if i < No. of Tuples.

**Step7**: $MSE_{total} = MSE_{total}$ / No. of Tuples. Store $MSE_{total}$.

**Step8**: Repeat Step 2-6 for no. of epoch size.

**Step9**: λ = λ + 0.1. Repeat by going to step2 with initialization of weights randomly if λ <= 1.0.

The ANN model is shown above with dimensions l, g, w and cut off frequency obtained from the output of ANN for the chosen dielectric substrate. The design is made and parametric variations are obtained for 80 observations, 60 are used for training and rest 20 is used for testing. The best learning rate is chosen by testing each starting from 0.1 to 1.0.The learning rate chosen at 0.1 turned to be the best learning rate. The neural network with 2 neurons in 1 hidden layer and best learning rate reduces the error to 0.003401 in 20 epochs only while testing the neural network. The obtained results from ANN were checked by designing in CST and the frequency response were matched mostly with respect to the result obtained in ANN. Incremental back propagation learning approach is followed in the training of neural network[9,10]. The training result is shown below with the least error of 0.003401.

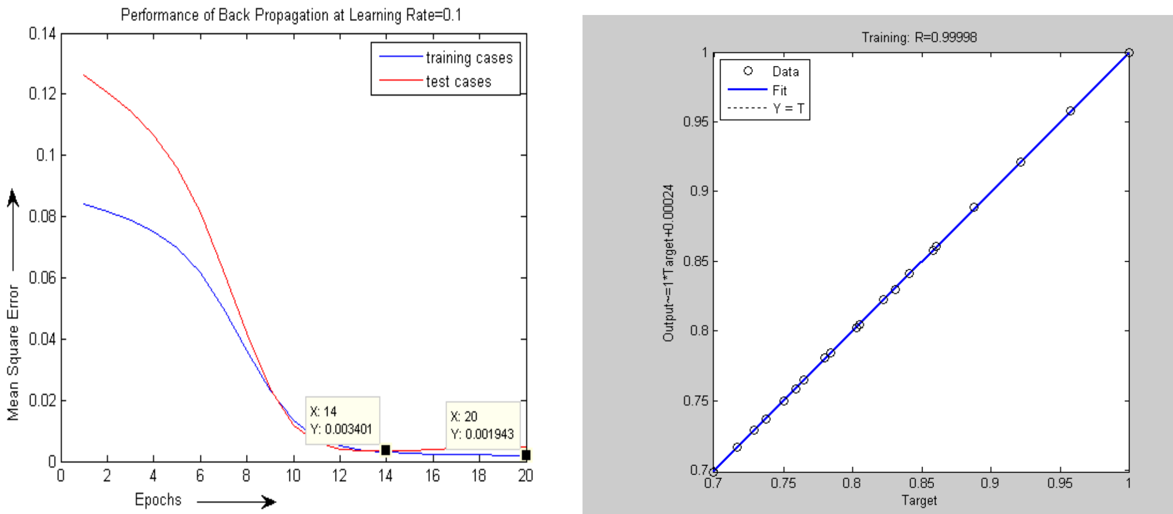



**Fig 5** ANN result and regression plot

After the neural network model is created different values of l, w, g are taken and the frequency response is calculated with the help of artificial neural network and the results are cross checked with the help of CST microwave studio, it is observed that neural network works efficiently in determining the accurate frequency of the microwave filter with dumbbell shaped DGS. When we chose l =10 ,g=0.1, w=5 (in mm) , the neural network output was found out to be 1.649 GHz , where the simulated result is shown below which shows the frequency response at 1.6527 GHz. The response is shown below in fig 6 which shows that neural network is working efficiently with least MSE 0.003401

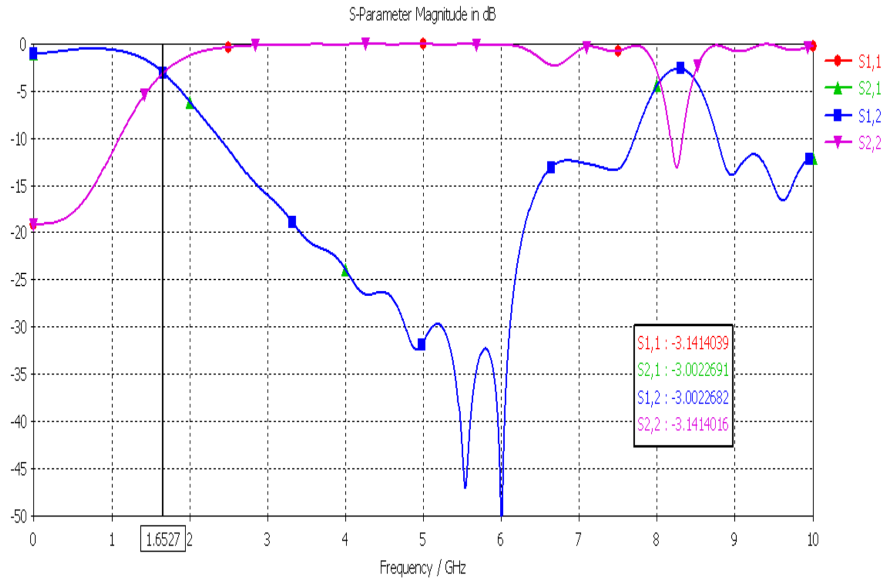



**Fig 6** frequency response obtained with CST

# VI. CONCLUSION

We designed the five elements LPF. After that dumbbell shaped defect is created in the ground plane. The addition of defects enhances the response of the filter as well as reduces the size. It consists of L-C parallel circuit having a resonant frequency characteristic. It is having band gap property, which is used in the many microwave applications. The frequency response of the dumbbell shaped defect is studied with respect to the dimension of its length, width and gap. The applications of artificial neural network for getting the frequency response of filter with respect to the dimensions of defects are done with the minimal error of 0.003401. Although training ANN model has spent little extra time, the successful intelligent model can quickly provide precise answers to the task in their training values range. Neural network efficiently worked to model frequency and the dimensions are optimized to give rise better response with the least error of 0.003401. The learning rate is chosen to be highly optimized one through iterations. The future scope of the work lies to implement Adaptive neuro fuzzy inference system (ANFIS) for the optimization and modeling of frequency response of microwave circuits , which will have better learning approach and higher degree of accuracy at a shorter time in comparison to ANN shown in [16].


# ACKNOWLEDGEMENTS

The authors would like to thank, CST Company, India for their support in CST EM tool. We are grateful to Prof. Rabindra Kishore Mishra , for his kind suggestions and guidance in this work . We are thankful to P.K. Patra and A.K. Panda for their kind help. The authors are grateful to the anonymous reviewers for their constructive & helpful comments & suggestions.

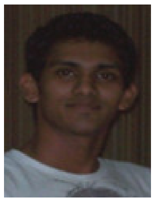

# REFERENCES


[1] Kim, J. P. and Park,W.S., "Microstrip lowpass filter with multislots on ground plane," Electronics Letters, Vol. 37, No. 25, pp. 1525 –1526, Dec. 2001.

[2] Yang, F., and Rahmat Samii, Y., "Electromagnetic band gap structures in antenna engineering", Cambridge University press, USA,2009

[3] Bharathi Bhat , Shiban K. Koul "Stripline-like Transmission Lines for Microwave Integrated Circuits" *New Age International (p) Ltd, Publishers,*2007..
[4] A.K Arya,M.V kartikeyan ,A.pattnaik "Defected ground structures in microstrip antenna: a review" in frequenz 64(2010)
[5] Roy, S.M., Karmakar, N.C., Balbin, I., "Quasi-Static Modeling of Defected Ground Structure", IEEE Transaction on Microwave Theory and Technique, vol.54, no.5, pp.2160 –2168, may 2006..
[6] Oskouei, H.D., Forooraghi, K. and Hakkak, M., "Guided and leaky wave characteristics of periodic defected ground structures", Progress in Electromagnetics Research, PIER 73, 15 –27, 2007
[7] Jung I. and Wang G., "Pattern Classification of Back-Propagation Algorithm Using Exclusive Connecting Network", World Academy of Science, Engineering and Technology 36 2007.
[8] ChattoPadhyay S., Kaur P., Rabhi F., and Acharya R.U., "An automated system to diagnose the severity of adult depression", EAIT, 2011
[9] Jha G.K., "Artificial Neural Network", IARI, 2006.
[10] http://www.softcomputing.net/ann_chapter.pdf
[11] Patnaik, A., Mishra, R.K., Patra, G.K., Dash, S.K., "An artificial neural network model for effective dielectric constant of microstrip line," IEEE Trans. on Antennas Propagation, Vol. 45, no. 11, p. 1697, November 1997.
[12] S.S pattnaik , D.C panda, S devi "A novel method of using Artificial Neural Networks to calculate input impedance of circular microstrip antenna"
[13] Bailer-Jones D.M.and Bailer-Jones C.A.L., "Modelling Data: Analogies in neural networks, simulated annealing and genetic algorithms" in Model-Based Reasoning: Science, Technology, Values, L. Magnani and N. Nersessian (eds.), New York: Kluer Academic/Plenum Publishers, 2002.
[14] R.K.Mishra and Patnaik, "*Designing Rectangular Patch Antenna Using the Neurospectral Method*", IEEE Transactions on Antennas and Propagation,AP-51,8 August 2003,pp.1914-1921.
[15] CST Design Studio , MATLAB and DEV CPP
[16] Guney, K. and N. Sarikaya, "A hybrid method based on combining artificial neural network and fuzzy inference system for simultaneous computation of resonant frequencies of rectangular, circular, and triangular microstrip antennas," IEEE Trans. Antennas Propagat., Vol. 55, No. 3, 659–668, 2007.

## Biographies



**Bhabani Sankar Nayak** is currently pursuing his B.Tech in dept of Electronics and communication engineering at National Institute of Science & Technology, Berhampur, Orissa. His research interest include Electromagnetic, antenna, microwave circuits, CAD, soft computing. He is currently working as research scholar at NIST under scholarship program.

**Subhendu Sekhar Behera** is currently pursuing his B.Tech in dept of computer science & engineering at National Institute of Science & Technology, Berhampur, Orissa. His research interest include soft computing, web designing, algorithm design.

**Atul Shah** is currently pursuing his B.Tech in dept of Electronics and communication engineering at National Institute of Science & Technology, Berhampur, Orissa. His research interest include intelligence system design, embedded systems.